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(54) **Data hiding method and data extracting method**

(57) In order to hide message information (m) in media information (M), the frequency transform of the message information (m) and the media information (M) are performed, and frequency spectra f_1 and f_2 are obtained. Next, from the frequency spectrum f_2 of the message information (m), a region containing feature frequency components representative of the features of the message information (m) in real space is extracted as the base region B. Then, n copies of the base region B are generated, and in frequency space, the n copies are dispersedly arranged. Also, by making the frequency components other than that equal to zero, a frequency spectrum f_3 is generated as intermediate information. Finally, the frequency spectrum f_3 and the frequency spectrum f_1 are added, and by performing the inverse frequency transform of the result, the message information (m) can be hidden in the media information (M).

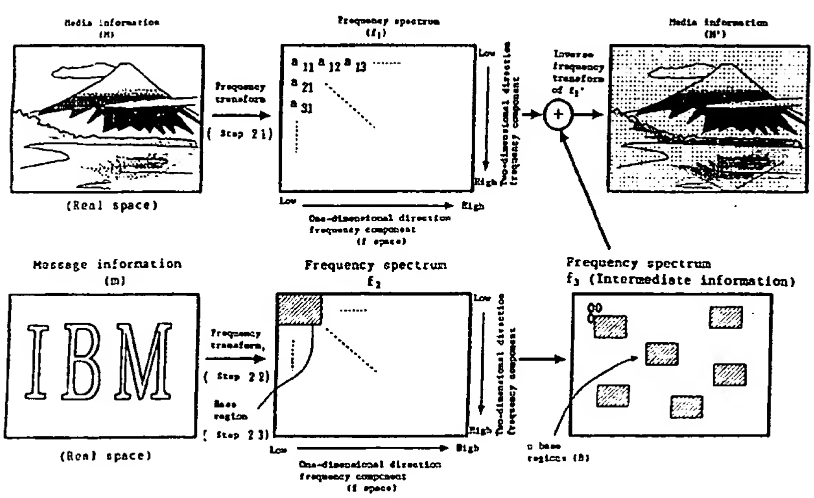

FIG. 3

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Description

The present invention relates to a data hiding method for hiding message data into media data and a data extracting method for extracting hidden data.

With the development of multimedia society, large quantities of digital video and audio information have been circulated on internet systems or as CD-ROM software. For digital video and audio information, any individual can easily create a perfect copy without degradation, so the illegal use and copyright protection are becoming problematic. In order to prevent a third party from illegally copying media data such as video and audio data, the technique of hiding additional information, such as the signature of an author, into original media data is becoming the focus of attention. When digital video data or other similar data is illegally copied, it could be known whether or not the copy is an illegal one by confirming the signature hidden in the copy and specifying the source. A hiding technique such as this is called data hiding.

As for the data hiding technique, a technique such as mentioned as follows is disclosed in "Nikkei Electronics 4-22 1996," issued on April 22, 1996. Figure 1 is a block diagram for explaining a conventional data hiding and extracting method. In the process of hiding an identification (ID) information, first, the frequency transform of media information, such as original dynamic images, still images, photographs, or audio, is performed by discrete cosine transform (DCT) or high-speed discrete Fourier transform (DFT) to obtain its frequency spectrum. Spectrum diffused and convoluted to this frequency spectrum of the media information is ID information. The ID information is a random specified to each purchaser of a work. The random-number generating algorithm employs a normal distribution, and the length is 1000. Then, the frequency spectrum of the media information to which the ID information was added is restored by inverse frequency transform to the original digital work having the hidden ID information. The digital work has the hidden ID information but is almost identical with the original work, so the purchaser cannot perceive the difference visually.

Conversely, in the process of extracting the ID information, first, the frequency transform of the digital work, thought of as an illegal copy, is performed to obtain its frequency spectrum and the frequency spectrum of the original work is also obtained. Then, the difference between these spectra is taken and compared with the ID information issued by the author. With this comparison, the purchaser of the work can be specified, so it can be judged whether or not the copy is illegal.

One of the features of the aforementioned technique is that frequency space is utilised for hiding data. That is, media information is transformed from real space to frequency space, and the frequency component in the frequency spectrum is operated based on ID information. Another feature is that a frequency region to be utilised is local. That is, the high-frequency component in the frequency spectrum of media information is not utilised and spectrum diffusion is performed only for a low-frequency region. The reason for this is that if ID information is diffused up to a high-frequency region, ID information is erased in compressing or decompressing the image. That is, this conventional technique spectrum-diffuses ID information locally in the frequency space of media information and hides the ID information in the entire real space of the media information.

The aforementioned conventional technique, however, has the disadvantage that message information (ID information) can be easily filtered out from media information by employing a frequency filter. For example, when media information with message information hidden therein is processed by employing a high-pass filter which filters out only a low-frequency component, the component of the high-frequency band remains unfiltered, but the component of the low-frequency band in which message information has been hidden is completely filtered out. Therefore, it is no longer possible to extract ID information from the media information that was output from a high-pass filter, and it is possible to hide different additional ID information.

Accordingly, it is the objective of the present invention to provide a data hiding method which has high resistance to removal or change of media information embedded into message information. Particularly, in the present invention it becomes possible to continue to effectively maintain hidden message information even when signal processing is performed by employing a frequency filter.

To solve the aforementioned problems, a first invention provides a data hiding method which embeds message information into media information. The data hiding method comprises the steps of:

(a) obtaining a frequency spectrum which contains a plurality of frequency components with respect to the message information;

(b) extracting a base region from the frequency spectrum of the message information, the base region being defined as a region which contains feature frequency components that represent features of the message information in real space;

(c) generating a plurality of copies of the base region and generating a frequency spectrum obtained by dispersedly arranging the respective copies in frequency space, as intermediate information; and

(d) hiding the message information into the media information by operating the frequency spectrum of the message information, based on the intermediate information.

Also, a second invention provides a data hiding

method which hides message information into media information. The data hiding method comprises the steps of:

(a) obtaining a frequency spectrum which contains a plurality of frequency components with respect to the message information;

(b) extracting a base region from the frequency spectrum of the message information, the base region being defined as a region which contains feature frequency components that represent features of the message information in real space;

(c) generating a plurality of copies of the base region and generating a frequency spectrum obtained by dispersedly arranging the respective copies in frequency space, as intermediate information; and

(d) hiding the message information into the media information by executing an arithmetic based on both the intermediate information and the media information.

Here, it is preferable that the base region contain a plurality of frequency components which represent external features of the message information in real space. Particularly when the media information is image information, it is preferable that the base regions be constituted by a plurality of low-frequency components which represent contour features of an image in real space.

Also, in the step (b), a plurality of base regions may be extracted. In this case, for each of the base regions.

The aforementioned copies each may have the same frequency component as the feature frequency component of the base region. Also, it is preferable that among the frequency components of the frequency spectrum as the intermediate information, frequency components other than positions at which the copies are arranged are zero.

Furthermore, it is preferable that the arithmetic in the step (d) be a binomial arithmetic more specifically addition. Note that a step of performing inverse frequency transform of a result obtained in the step (d) is executed when the arithmetic in the step (d) is executed in frequency space.

A third invention provides a data extraction method which extracts message information from media information with the message information hidden multiply in frequency space. The data extraction method comprises the steps of:

(a) obtaining, as first intermediate information, a frequency spectrum which has a plurality of base regions by operating the media information with the message information hidden therein, each of the base regions containing feature frequency components which represent features of the message information in real space;

(b) specifying at least one of the base regions from the frequency spectrum obtained as the first intermediate information;

(c) generating a frequency spectrum obtained by arranging the feature frequency components of the base region at predetermined positions on frequency space, as second intermediate information; and

(d) extracting the message information hidden into the media information by performing inverse frequency transform of the second intermediate information.

A fourth invention provides a data extraction method which extracts message information from media information with the message information hidden multiply in frequency space. The data extraction method comprises the steps of:

(a) obtaining a frequency spectrum which has a plurality of frequency components with respect to first intermediate information obtained by an arithmetic based on both the media information with the message information hidden therein and the media information with no message information hidden therein;

(b) specifying at least one of the base regions from the frequency spectrum of the first intermediate information each of the base regions containing feature frequency components which represent features of said message information in real space;

(c) generating a frequency spectrum obtained by arranging the feature frequency components of the base region at predetermined positions on frequency space, as second intermediate information; and

(d) extracting the message information hidden into the media information by performing inverse frequency transform of the second intermediate information.

Here, it is preferable that the arithmetic in the aforementioned step (a) be a binomial arithmetic. More specifically, it is preferable that the arithmetic in the step (a) be the difference between the media information with the message information hidden therein and the media information with no message information hidden therein

Also, on the frequency spectrum of the first intermediate information, the base regions are dispersed and multiply arranged.

In the aforementioned step (b), the base region may be specified by giving positional information which specifies a position of the base region in frequency space.

Also, in the aforementioned step (c), the base region may be arranged by giving an arranging rule which specifies a position of the base region in frequency space.

Furthermore, it is preferable that among the frequency components of the frequency spectrum as the second intermediate information, frequency components other than positions at which the base regions are arranged are zero.

In such a structure, a plurality of copies of the base region are dispersedly arranged in frequency space. That is, the base region is copied multiply in various frequency bands. Therefore, even in the case where the frequency component in a certain frequency band is filtered out by a frequency filer and where the copy arranged on that portion is lost, the contents of the base region can be specified from the copies existing in other bands. The respective copies have the same frequency component as the feature frequency component of the base region.

Therefore, if one copy can be specified, all feature frequency components can be extracted. Since the feature frequency component represents the feature of the message information in real space, the message information can be reconstructed by extraction of the feature frequency component.

How the invention may be carried out will now be described by way of example only and with reference to accompanying drawings in which:

Figure 1 is a block diagram for explaining data hiding and extraction in background art;

Figure 2 is a flowchart of a procedure of embedding data;

Figure 3 is a schematic diagram for explaining data embedding;

Figure 4 is a schematic view for explaining the state when base regions are arrayed in multiple in frequency space;

Figure 5 is a flowchart showing a procedure of extracting message information;

Figure 6 is a schematic diagram for explaining data extraction;

Figure 7 is a diagram showing the halftoned image of digital message information displayed on a display device;

Figure 8 is a conceptual diagram for explaining the embedding of data in the case where a plurality of base regions have been set;

Figure 9 is a conceptual diagram for explaining the embedding of another data;

Figure 10 is a block diagram of a system which embeds message information into media information; and

Figure 11 is a block diagram of a system which extracts message information from the media information with the message information hidden multiply in frequency space.

A data hiding method for hiding message information into media information will hereinafter be described based on Figures 2 and 3. Figure 2 is a flowchart of the data embedding procedure in an embodiment of the present invention, and Figure 3 is a schematic diagram for explaining data embedding.

<u>Frequency Transform of Media Information M (step 21)</u>:

First, media information (M) and message information (m) are prepared. The media information (M) is an object, in which data is hidden, and such information is either still image data, dynamic image data, voice data, or, etc. In the following description, still images such as those shown in Figure 3 are described as examples of a media image.

Also, the message information (m) is information which is hidden into media information (M), and in the following description, a binary image "IBM" consisting of relatively low frequency components, such as the one shown in Figure 7(a), will be described as an example. The frequency transform of a still image as media information (M) is performed. The frequency transform can employ various known frequency transforms such as sine transform, Fourier transform, discrete Fourier transform (DFT), and wavelet transform. By employing frequency transforms suitable for the features of message information, conversion efficiency and reliability can be enhanced. By performing the frequency transform of media information (M), frequency spectrum f_1 is obtained. The frequency spectrum f_1 contains a great number of frequency components (a) in the form of a matrix, as shown in Figure 3, and the horizontal direction and vertical direction represent a one-dimensional direction and a two-dimensional direction, respectively. Note that the one-dimensional direction represents a higher frequency component as it goes right and the two-dimensional direction represents a higher frequency component as it goes down.

<u>Frequency Transform of Message Information (m) (step 22)</u>:

By performing the frequency transform of message information (m) used as a binary image, there is obtained frequency spectrum f_2 where a great number of frequency components (b) are arrayed in the form of a

matrix.

Extraction of Base Region B (step 23):

Base region B is extracted from the frequency spectrum f2 of message information (m). This base region B is constituted by a plurality of feature frequencies which represent the external feature of message information (m) in real space. In a general image, a frequency component expressing the contour feature is often part of the entire frequency space. For example, a large and simple figure pattern, which can be easily perceived by humans, can be expressed only by relatively low-frequency components.

Figure 7 depicts the halftoned image of digital message information displayed on a display device. The frequency spectrum of a binary image of Figure 7(a), constituted by 384 x 256 pixels, is obtained and a specific low-frequency band is made a base region. Here, as an example, each frequency component expressed by bij (where 1_i_ 50 (one-dimensional direction) and 1_j_50 (two-dimensional direction)) is specified as a base region. Then, the frequency components that are not contained in the base region are all made zero. Next, a new frequency spectrum obtained by this operation is returned to real space again, and consequently, an image such as that shown in Figure 7(b) is obtained. Although the picture quality has been degraded due to the dull edge of the image and fringe patterns, the picture quality has been maintained to the extent that requisite information can be extracted. From this result it follows that the contour feature of a simple image can be roughly expressed only by the low-frequency components within the aforementioned base region. Therefore, each frequency component within this base region is referred to as a feature frequency component.

The base region can be determined automatically by referring to the value of each frequency component of a frequency spectrum. In general, it can be said that a frequency component with a larger value is an important component to express the image. Therefore, by presetting a threshold value which gives a criteria for judging the importance of a frequency component, the frequency components of a frequency spectrum greater than threshold value are all extracted. Then, a place at which extracted frequency components are particularly concentrated (a place forming a region greater than a predetermined standard) is specified as a base region.

Figure 4 is a schematic view for explaining the state when base regions are multiply arrayed in frequency space. In the frequency spectrum f2 shown in the figure, the frequency component in the upper right region indicated by oblique lines is the feature frequency component. Hence, a block containing a low-frequency component representative of a binary image feature is cut out as the base region.

It is noted that the feature frequency component does not always have to be a low-frequency component. The reason is that, in an image with a complicated external feature such as a lattice pattern, a higher-frequency component becomes of importance and therefore the feature frequency component can be different depending upon images. Therefore, the base region in the present invention is defined as a region which contains a plurality of feature frequency components representative of external features of message information (m) in real space. Thus, the feature frequency component is not limited only to a region containing a low-frequency component.

Generation of Intermediate Information (step 24):

The basis reference region B obtained in step 23 is repeatedly copied n times in frequency space to generate intermediate information (frequency spectrum f_3). That is, n copies of the base region are generated and the respective copies are dispersedly arranged in frequency space.

In the frequency spectrum f_3 shown in Figure 4, n copies of the base region B extracted in step 23 are dispersedly arranged. Each frequency component of the arranged respective copies has the same value as a feature frequency component corresponding to the position of the base region. For example, each frequency component of the uppermost row in a certain position at which the copy in the frequency spectrum f_3 is arranged is caused to correspond to the frequency component of the uppermost row in the base region, so the frequency component becomes "b11, b12, ..., b1m" from left. This operation is executed for all positions at which the copies of the base region B are arranged. Then, the frequency components other than the positions at which copies are arranged (the parts in the frequency spectrum f_3 of Figure 4 indicated by oblique lines) are made equal to zero.

In step 23, positional information on where the position of the aforementioned n copes are arranged in frequency space is stored as a key K. This key K becomes necessary when message information is extracted. Also, information on the size of a base region is stored as the occasion may demand. The arranged positions may always be fixed positions regardless of an object to be embedded, but it is preferable to make the arranged positions different for each object from the viewpoint of a countermeasure to change.

In the case where the arranged positions are changed according to circumstances, a position series generation algorithm, such as that described for example in Japanese Patent Application No.8-159330, can be employed. When the algorithm is employed, the positions are arranged so that they are put aside to a specific band within frequency band, in view of resistance to frequency filters.

Addition of Frequency Spectra (step 25):

The frequency spectrum f_3 of an intermediate information and the frequency spectrum f_1 of media information (M) are added.

Inverse Frequency Transform (step 26):

The inverse frequency transform of the frequency spectrum, obtained by the addition in step 25, is performed to obtain media information (M') in which message information was hidden. Because this media information (M') has been given a process based on message information (m), it is different from the original media information (M) in the strict sense of the word. However, the difference is nearly unperceivable.

The addition of frequency spectrum f3 and media information can be performed in real space. In this case, it is desirable to multiply data to be embedded by a constant so that the inverse frequency transform of the frequency spectrum f_3 is performed to maximally suppress degradation of picture quality which is caused due to addition, and it is desirable to shorten the value.

Note that in the case where addition is performed for each pixel in real space in this way, it is a matter of course that step 26 does not need to be executed.

Extraction of Data

For a method of extracting message information from media information (M') with the message information multiply hidden in frequency space by the aforementioned hiding method, a description will next be described based on Figures 5 and 6. Figure 5 is a flowchart showing the procedure of extracting message information, and Figure 6 is a schematic diagram for explaining extraction of data. Basically, the following data are needed in order to extract message information.

(1) Media information (M') in which message data was hidden
(2) Original media information (M)
(3) Key K as positional information

Generation of Differential Information (I) (First Intermediate Information) (step 51):

By taking in real space the difference between the media information (M') in which message information (m) was hidden and the original media information (M), differential information is obtained as first intermediate information.

Frequency Transform of Differential Information (I) (step 52):

By performing the frequency transform of the differential information (1), the frequency spectrum f_4 is obtained. Note that the difference in step 51 may be calculated not only in real space but also in frequency space.

In this case, the frequency spectra of the media information (M') and the original media information (M) are first obtained. Then, the difference between these is taken in frequency space to obtain the frequency spectrum f_4. In the frequency spectrum f_4 obtained in this way, the base regions are dispersed and multiply arranged.

Extraction of Base Region B (step 53):

At least one base region B is extracted from the frequency spectrum f_4. In order to specify the position of the base region B in frequency space, the key K is employed. and at least one region of the same size as the base region is taken out. On the premise that the base region was taken out, there is the need to inform an extractor of the size of the base region, for example, by containing it in the key information. If media information (M') is in an ideal state having no damages, the frequency spectrum f_4 is identical with the aforementioned frequency spectrum f3. Therefore, since n base regions have been arranged in multiple, a maximum of n base regions can be taken out in the ideal state. However, when the media information (M') is damaged by a frequency filter or an analogue copy, some of the base regions are lost. Therefore, there are cases where the n base regions cannot be all taken out. However, it is noted that, even in this case, if any one of the base regions can be extracted, the message information can be effectively extracted.

Generation of Second Intermediate Information (I') (step 54):

By arranging the base region B at a predetermined position on the frequency space, frequency spectrum f_5 is generated as second intermediate information (I').

By arranging the base region B at a predetermined position on the frequency space, frequency spectrum f_5 is generated as second intermediate information (I'). An arrangement rule about where the position of the base region B is arranged in frequency space has previously been given, and the base region B is arranged according to this rule. In this embodiment, it is assumed that the base region B is arranged at the upper left portion which is the low-frequency region of the frequency spectrum f_5 (see Figure 6). The value of each frequency component in the frequency spectrum f_5 is the value of the feature frequency component of the basic frequency region B for the portions where the base regions B were arranged, and the frequency components other than that are made zero.

Inverse Frequency Transform (step 55):

The inverse frequency transform of the frequency

spectrum f_5 is performed. With this, the message information (m) hidden into the media information (M') is extracted.

Thus, in the aforementioned method, since the base regions representing the feature of the message information are dispersedly arranged in multiple in the frequency space of the media information, the embedded message information has high resistance to processing based on a frequency filter and to analogue copying. The frequency filter is operated locally with respect to the frequency space, so there is a low possibility that all of the aforementioned copies are destroyed. Therefore, if any of the copies is present without being damaged, the base region can be specified and therefore the message information can be interpreted.

An embedded message information can not be taken out if the original media information (M) and the key K are not present. Therefore, the original media information and the key information fulfil the role of a key for cryptographing, so the forgery or change of data is very difficult.

Furthermore, the amount of data required for taking out embedded data is reduced and of practical use. The data required for taking out are original media information (M) and a key K for specifying the copied position of the base region.

While the aforementioned embodiment has been described with reference to the case of a single base region, the present invention is applicable to even the case of a plurality of base regions. Figure 8 is a conceptual diagram for explaining embedding of data in the case where a plurality of base regions have been set. By extracting 7 base regions (B_1 through B_7) from the frequency spectrum f_2 of message information and making multiple copies of all base regions, frequency spectrum f_3 is generated as intermediate information. Note that Figure 8 depicts the case of a multiple degree 2.

Also, although the aforementioned embodiment has been described with reference to the case where addition and subtraction are used for the embedding and extraction of data, the present invention is not limited to addition and subtraction. That is, the present invention can employ any algorithm so long as original data can be reconstructed from the result of an algorithm performed based on certain data when data is hidden. Therefore, various algorithms, including a reversible binomial algorithm, are considered.

The algorithm used here is a conception including replacement of frequency components. Figure 9 is a conceptual diagram for explaining the embedding of data in another embodiment. The frequency transform of media information (M) is performed to obtain frequency spectrum f_1 and, at the same time, base region B is copied multiply in frequency space to obtain frequency spectrum f_3 as intermediate information. The procedure up to here is the same as the description of Figure 3. Next, as an algorithm, among the frequency components (a) of the frequency system f_1 corresponding to the positions of the base regions, only the frequency components corresponding to the positions of the base regions B are replaced.

That is, the respective frequency components (a) corresponding to the positions of the regions (i.e., copies of base regions) indicated by oblique lines in the frequency spectrum f_3 of Figure 9 are replaced with corresponding feature frequency components (b).

In the aforementioned way, all frequency components (a) in the regions corresponding to the arranged positions of copies in frequency spectrum f_1 are replaced with the feature frequency components (b) of the base regions B. The information on the positions at which copies are arranged is stored as a key K. By performing the inverse frequency transform of the frequency spectrum given such an arithmetic of replacement, media information (M') embedded with message information is obtainable.

On the other hand, in the case where message information is extracted, the positions at which copies are arranged in the frequency space of the media information (M') are specified based on the stored key K. Thereafter, by executing a similar procedure as the aforementioned method, the message information can be extracted.

In the embodiment of Figure 9, the feature frequency components of the basic regions B are directly the frequency components of the media information, so there is no need to employ the original media information (M) when message information is extracted. That is, message information can be extracted only by media information (M') and key K. Therefore, there is the advantage that the amount of data to be stored can even be further reduced.

In the embodiment of Figure 9, in order to suppress degradation of picture quality of media information it is desirable to make copies at the positions of the frequency spectrum f_1 which are unlikely to have too-great of an influence on picture quality. Although the processing of an image depends upon the feature of message information, it is undesirable, in a simple image such as that shown in Figure 7, to operate a low-frequency band form the viewpoint of prevention of picture quality degradation. Nevertheless, even if a frequency band which is too high were operated, the copy of the base region would be easily lost if a third party processes data. Therefore, in such an image it is desirable to arrange copies at an intermediate frequency band.

A description will be made of a system which realises the aforementioned data hiding method. Figure 10 is a block diagram of a system which embeds message information into media information. On a storage device 11, media information (M) and message information (m) are stored.

Frequency transform means 12 obtains the frequency spectra of media information (M) and message information (m). The obtained frequency spectra are stored on a predetermined address region of main mem-

ory 13. Base-region extraction means 14 extracts base region B from the frequency spectrum of the message information (m) stored on the main memory 13, and the base region B contains feature frequency components which represent the feature of the message information in real space. Intermediate-information generation means 15 generates a plurality of copies of the base region B obtained by the base-region extraction means 14 and also generates a frequency spectrum as an intermediate information by dispersing and arranging the respective copies of the base region B in frequency region. The intermediate-information generation means 15 further outputs a key K which is information on the arranged positions of the copies of the base region B. Algorithm means 16 hides message information (m) into media information (M) by operating the frequency spectrum of the media information stored on the main memory 13, based on the frequency spectrum as an intermediate information. The inverse frequency transform of the operated frequency spectrum is performed by inverse frequency transform means 17, and media information M' embedded with message information is output.

A description will next be made of a system which realises the aforementioned data extracting method. Figure 11 is a block diagram of a system which extracts message information from the media information with the message information hidden multiply in frequency space. On a storage device 21, media information (M') is stored. First generation means obtains a frequency spectrum as first intermediate information by operating the media information (M').

The first intermediate information has a plurality of base regions B including a feature frequency component representative of the feature of message information in real space and is stored on a predetermined address region of main memory 13. Specification means 24 specifies at least one base region B from frequency spectrum of the first intermediate information stored on the main memory 23, based on an archived key K. Second generation means 25 generates a frequency spectrum as second intermediate information by arranging the feature frequency component of the base region B at a predetermined position on frequency space. Then, extraction means 26 extracts and outputs the message information (m) hidden in the media information (M') by performing the inverse frequency transform of the frequency spectrum of the second intermediate information.

The program which realises the aforementioned data embedding method is generally stored on a storage medium. Here, the storage medium is, for example, a floppy disk, a hard disk, CD-ROM, MO, DVD, a semiconductor memory, and so on. This program has the following steps of:

(a) obtaining a frequency spectrum which contains a plurality of frequency components with respect to said message information;

(b) extracting a base region from said frequency spectrum of the message information, the base region being defined as a region which contains feature frequency components that represent features of said message information in real space;

(c) generating a plurality of copies of said base region and generating a frequency spectrum obtained by dispersedly arranging the respective copies in frequency space, as intermediate information; and

(d) hiding said message information into said media information by operating said frequency spectrum of the message information, based on said intermediate information.

In addition, the program which realises the aforementioned data extraction method has the following steps of:

(a) obtaining, as first intermediate information, a frequency spectrum which has a plurality of base regions by operating said media information with said message information hidden therein, each of the base regions containing feature frequency components which represent features of said message information in real space;

(b) specifying at least one of the base regions from said frequency spectrum obtained as said first intermediate information;

(c) generating a frequency spectrum obtained by arranging said feature frequency components of said base region at predetermined positions on frequency space, as second intermediate information; and

(d) extracting said message information hidden into said media information by performing inverse frequency transform of said second intermediate information.

The data hiding technique employing the present invention in the aforementioned way has high resistance to processing based on a frequency filter and to analogue copying, and consequently, the data hiding technique can effectively maintain and extract hidden message information even when such processing is performed.

The data hiding method of the present invention may have any of the following features:

a) The base region contains a plurality of frequency components which represent external features of said message information in real space;

b) The media information is image information and said base region is constituted by a plurality of low-frequency components which represent contour features of an image in real space;

c) A plurality of base regions are extracted from said frequency spectrum of the message information, the base regions being defined as regions which contain feature frequency components that represent features of said message information in real space.

d) The copies each have the same frequency component as the feature frequency component of the base region;

e) Among the frequency components of said frequency spectrum as said intermediate information, frequency components other than positions at which said copies are arranged are zero;

f) The step of generating a plurality of copies (n) of said base region and generating a frequency spectrum (f_3) obtained by dispersedly arranging the respective copies in frequency space, as intermediate information is executed for each of the base regions extracted by step c) above;

g) The step of hiding said message information in said media information wherein the arithmetic is a binomial arithmetic;

h) The arithmetic in g) above is addition;

i) The data hiding method may, further comprise a step of performing inverse frequency transform of a result obtained in g) above when the arithmetic is executed in frequency space.

The data extraction method of the present invention may have any of the following features:

j) In the step of obtaining a frequency spectrum (f_1, f_2) which has a plurality of frequency components with respect to first intermediate information (f_3) obtained by an arithmetic based on both said media information (m) with said message information hidden therein and said media information (m) with no message information hidden therein the arithmetic is a binomial arithmetic;

k) In j) above the arithmetic is the difference between said media information with said message information hidden therein and said media information with no message information hidden therein;

l) On said frequency spectrum of the first intermediate information, said base regions are dispersed and multiply arranged;

m) In specifying at least one of the base regions (B) from said frequency spectrum obtained as said first intermediate information (f_3) said base region can be specified by giving positional information which specifies a position of said base region in frequency space.

n) In generating a frequency spectrum obtained by arranging said feature frequency components of said base region (B) at predetermined positions on frequency space, as second intermediate information (54); and base region can be arranged by giving an arranging rule which specifies a position of said base region in frequency space.

o) Among the frequency components of said frequency spectrum as said second intermediate information, frequency components other than positions at which said base regions are arranged are zero.

Claims

1. A data hiding method for embedding message information (m) in media information (M) characterised by the steps of:

   (a) obtaining a frequency spectrum (f_1, f_2) which contains a plurality of frequency components with respect to said message information (m);

   (b) extracting a base region (B) from said frequency spectrum of the message information, the base region (B) being defined as a region which contains feature frequency components that represent features of said message information in real space;

   (c) generating a plurality of copies (η) of said base region and generating a frequency spectrum (f_3) obtained by dispersedly arranging the respective copies in frequency space, as intermediate information; and

   (d) hiding said message information (m) in said media information (M) either by operating said frequency spectrum (f_1, f_2) of the message information, (m) based on said intermediate information or by executing an arithmetic based on both said intermediate information (f_3) and said media information (M).

2. A data extraction method for extracting message information (m) from media information (M) with said

message information hidden in frequency space, characterised by the steps of:

(a) obtaining, as first intermediate information (f3), a frequency spectrum which has a plurality of base regions (B) by operating said media information (M) with said message information (m) hidden therein, each of the base regions (B) containing feature frequency components which represent features of said message information (m) in real space;

(b) specifying at least one of the base regions (B) from said frequency spectrum obtained as said first intermediate information (f_3);

(c) generating a frequency spectrum obtained by arranging said feature frequency components of said base region (B) at predetermined positions on frequency space, as second intermediate information (54); and

(d) extracting said message information (m) hidden in said media information (M) by performing inverse frequency transform of said second intermediate information (54).

3. A data extraction method for extracting message information (m) from media information (M) with said message information hidden in frequency space, characterised by the steps of:

(a) obtaining a frequency spectrum (f_1, f_2) which has a plurality of frequency components with respect to first intermediate information (f_3) obtained by an arithmetic based on both said media information (m) with said message information hidden therein and said media information (m) with no message information hidden therein;

(b) specifying at least one of the base regions (B) from said frequency spectrum of the first intermediate information (f_3) each of the base regions containing feature frequency components which represent features of said message information in real space;

(c) generating a frequency spectrum obtained by arranging said feature frequency components of said base region (B) at predetermined positions on frequency space, as second intermediate (54) information; and

(d) extracting said message information (m) hidden into said media information (M) by performing inverse frequency transform of said second intermediate information (54)

4. A system for embedding message information (m) in media information (M), characterised by the steps of:

(a) means (12) for obtaining a frequency spectrum (f_1, f_2) which contains a plurality of frequency components with respect to said message information (m);

(b) an extractor (14) for extracting a base region (B) from said frequency spectrum of the message information (m), the base region (B) being defined as a region which contains feature frequency components that represent features of said message information (m) in real space;

(c) a generator (15) for generating a plurality of copies of said base region (B) and generating a frequency spectrum obtained by dispersedly arranging the respective copies in frequency space, as intermediate information (f_3); and

(d) means (16) for hiding said message information (m) in said media information (m) by operating said frequency spectrum of the message information (m), based on said intermediate information (f_3).

5. A system for extracting message information (m) from media information (M) with said message information hidden in frequency space, characterised by the steps of:

(a) means (12) for obtaining, as first intermediate information (f3), a frequency spectrum (f_1, f_2) which has a plurality of base regions (B) by operating said media information (M) with said message information (m) hidden therein, each of the base regions (B) containing feature frequency components which represent features of said message information (m) in real space;

(b) a specifier (24) for specifying at least one of the base regions (B) from said frequency spectrum obtained as said first intermediate information (f_3);

(c) a generator (25) for generating a frequency spectrum obtained by arranging said feature frequency components of said base region (B) at predetermined positions on frequency space, as second intermediate information (54); and

(d) an extractor (26) for extracting said message information (m) hidden in said media information (M) by performing inverse frequency transform of said second intermediate informa-

tion (54).

6. A program storage medium (11) for executing a process of hiding message information (m) in media information (M) by a computer, the medium characterised by the steps of:

(a) obtaining a frequency spectrum which contains a plurality of frequency components (f_1, f_2) with respect to said message information (m);

(b) extracting a base region (B) from said frequency spectrum of the message information (m), the base region (B) being defined as a region which contains feature frequency components that represent features of said message information (m) in real space;

(c) generating a plurality of copies of said base region (B) and generating a frequency spectrum obtained by dispersedly arranging the respective copies in frequency space, as intermediate information (f_3); and

(d) hiding said message information (m) in said media information (M) by operating said frequency spectrum of the message information (m), based on said intermediate information (f_3).

7. A program storage medium (11) for executing a process of extracting message information (m) from media information (M) with said message information hidden in frequency space by a computer, the medium characterised by the steps of:

(a) obtaining, as first intermediate information (f_3), a frequency spectrum which has a plurality of base regions (B) by operating said media information (M) with said message information (m) hidden therein, each of the base regions (B) containing feature frequency components which represent features of said message information (m) in real space;

(b) specifying at least one of the base regions (B) from said frequency spectrum obtained as said first intermediate information (f_3);

(c) generating a frequency spectrum obtained by arranging said feature frequency components of said base region (B) at predetermined positions on frequency space, as second intermediate information (54); and

(d) extracting said message information hidden (m) in said media information (M) by performing inverse frequency transform of said second intermediate information (54).

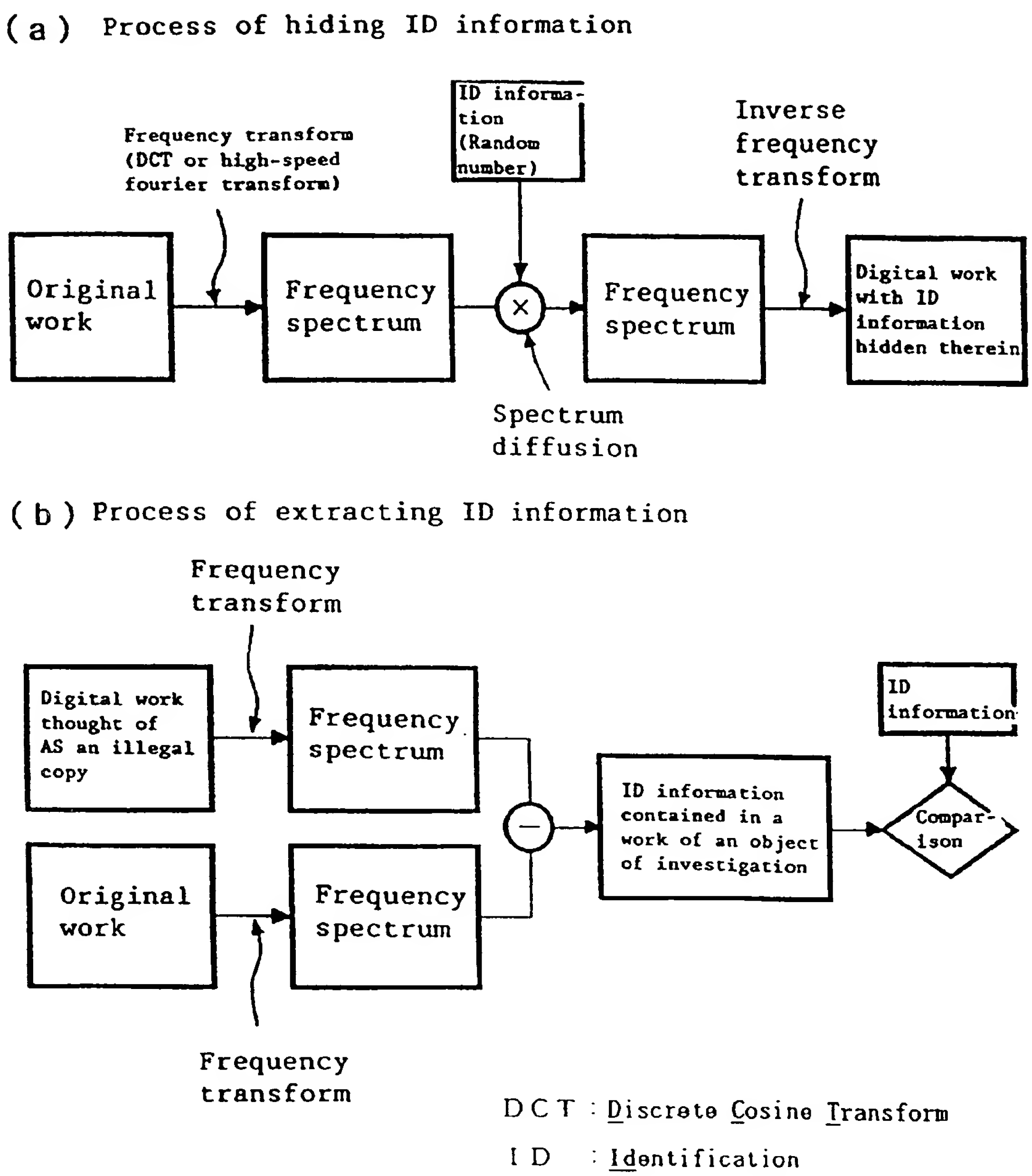

(a) Process of hiding ID information
Frequency transform (DCT or high-speed fourier transform)
ID information (Random number)
Inverse frequency transform
Original work
Frequency spectrum
Frequency spectrum
Digital work with ID information hidden therein
Spectrum diffusion
(b) Process of extracting ID information
Frequency transform
Digital work thought of AS an illegal copy
Frequency spectrum
ID information
ID information contained in a work of an object of investigation
Compar-ison
Original work
Frequency spectrum
Frequency transform
DCT : Discrete Cosine Transform
ID : Identification

FIG. 1

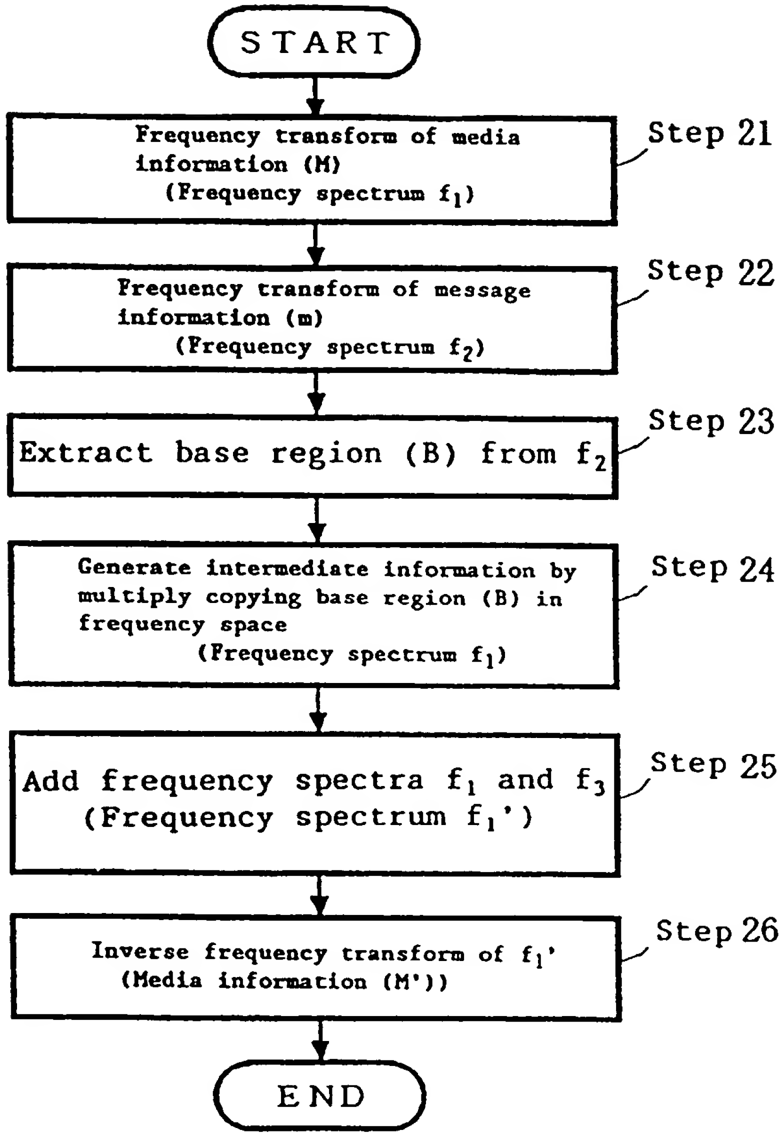

START
Frequency transform of media information (M) (Frequency spectrum f_1)
Step 21
Frequency transform of message information (m) (Frequency spectrum f_2)
Step 22
Extract base region (B) from f_2
Step 23
Generate intermediate information by multiply copying base region (B) in frequency space (Frequency spectrum f_1)
Step 24
Add frequency spectra f_1 and f_3 (Frequency spectrum f_1')
Step 25
Inverse frequency transform of f_1' (Media information (M'))
Step 26
END

FIG. 2

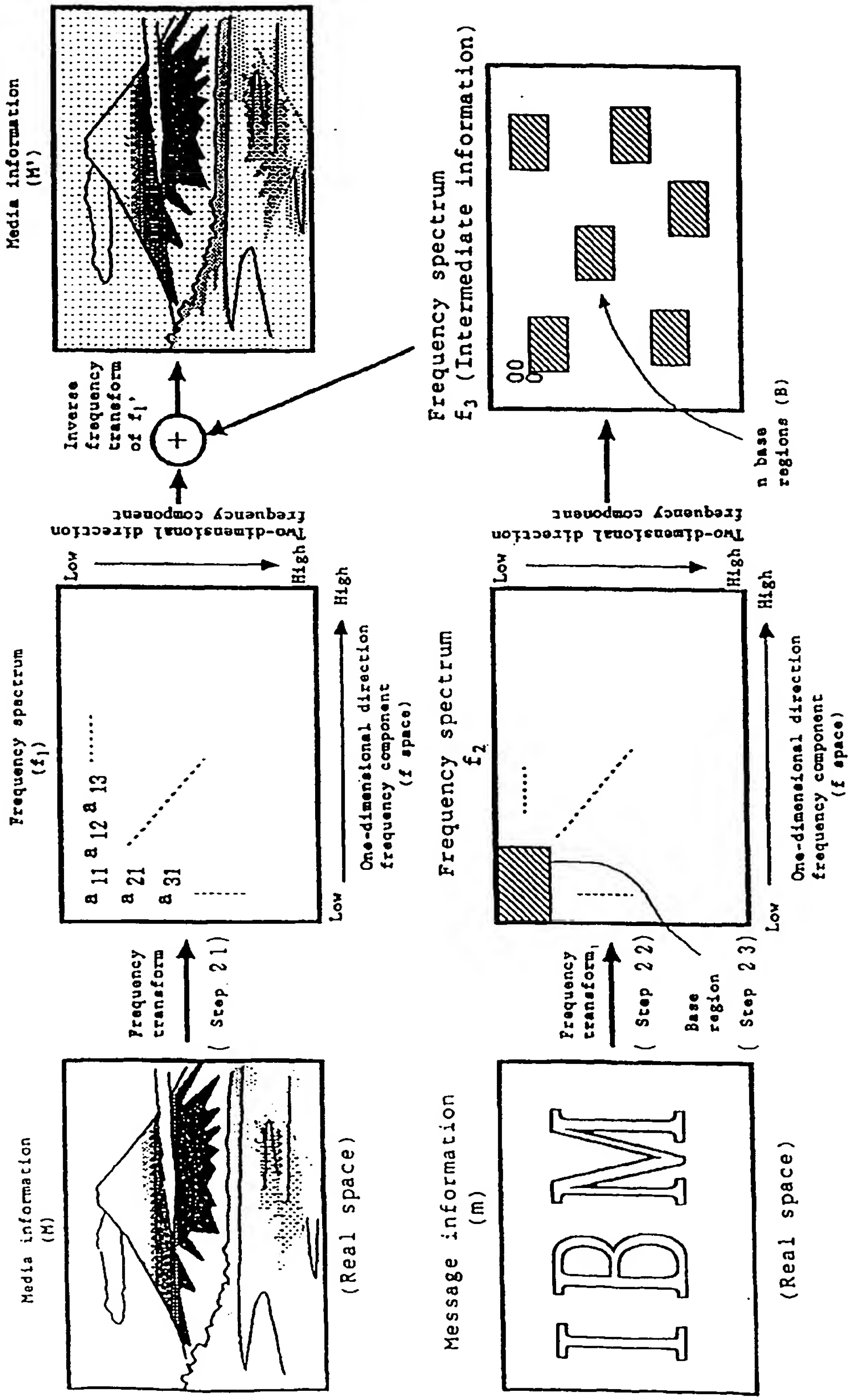

Media information
(M)
(Real space)
Frequency transform
(Step 21)
Frequency spectrum
(f_1)
a_{11} a_{12} a_{13} ......
a_{21}
a_{31}
Low
High
One-dimensional direction frequency component
(f space)
Two-dimensional direction frequency component
Inverse frequency transform of f_1'
Media information
(M')
Message information
(m)
IBM
(Real space)
Frequency transform
(Step 22)
Base region
(Step 23)
Frequency spectrum
f_2
Frequency spectrum
f_3 (Intermediate information)
00
0
n base regions (B)

FIG. 3

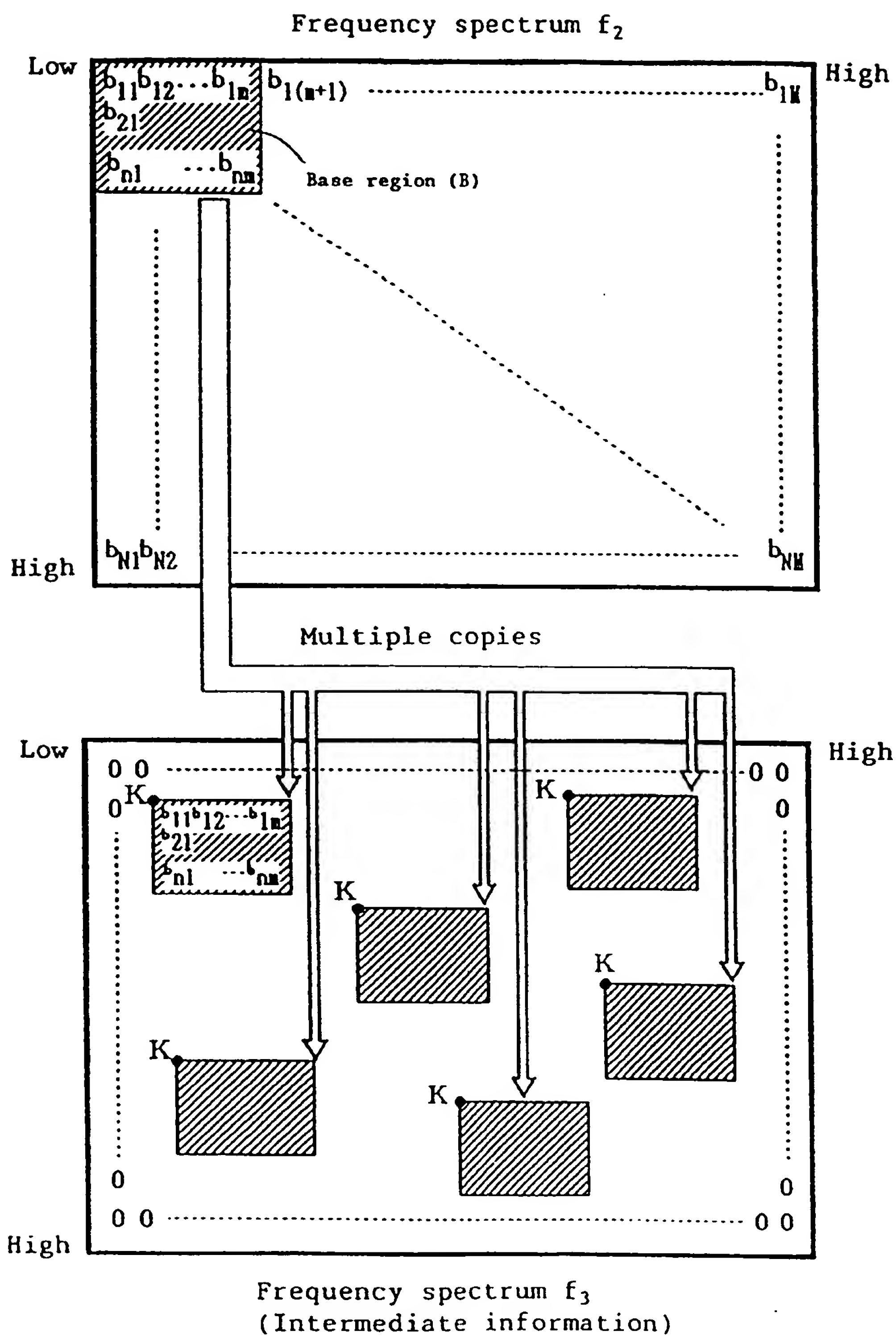

Frequency spectrum f2
Low
High
b11 b12 ... b1m b1(m+1) ... b1M
b21
bn1 ... bnm
Base region (B)
High
bN1 bN2 ... bNM
Multiple copies
Low
High
0 0 ... 0 0
0
K
b11 b12 ... b1m
b21
bn1 ... bnm
0 0 ... 0 0
High
Frequency spectrum f3
(Intermediate information)

FIG. 4

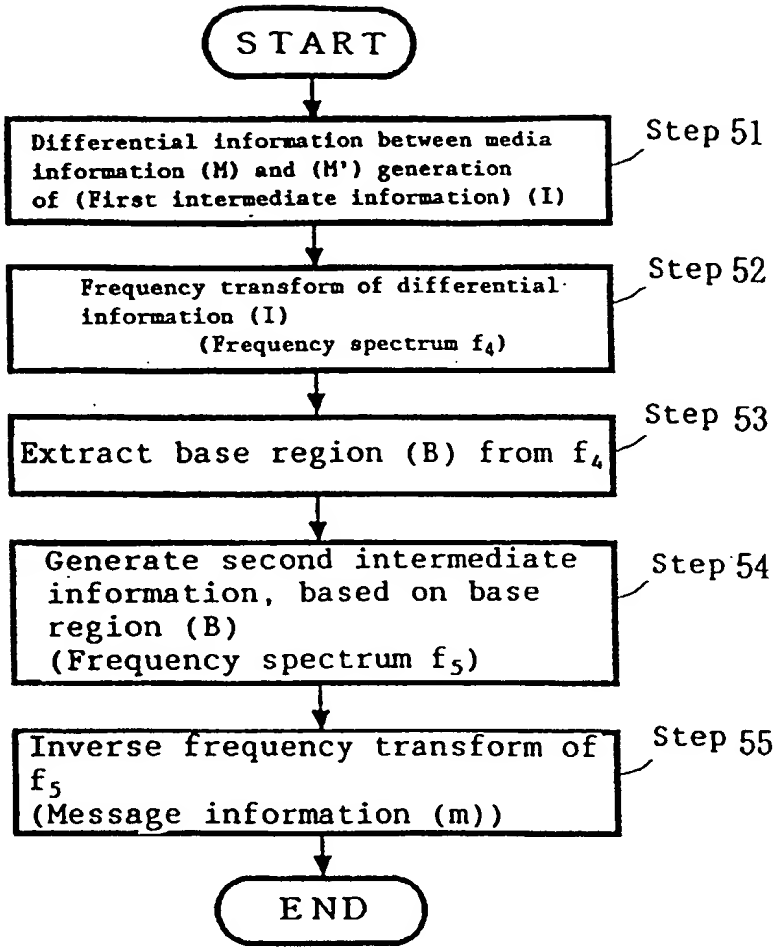

START
Differential information between media information (M) and (M') generation of (First intermediate information) (I)
Step 51
Frequency transform of differential information (I) (Frequency spectrum f_4)
Step 52
Extract base region (B) from f_4
Step 53
Generate second intermediate information, based on base region (B) (Frequency spectrum f_5)
Step 54
Inverse frequency transform of f_5 (Message information (m))
Step 55
END

FIG. 5

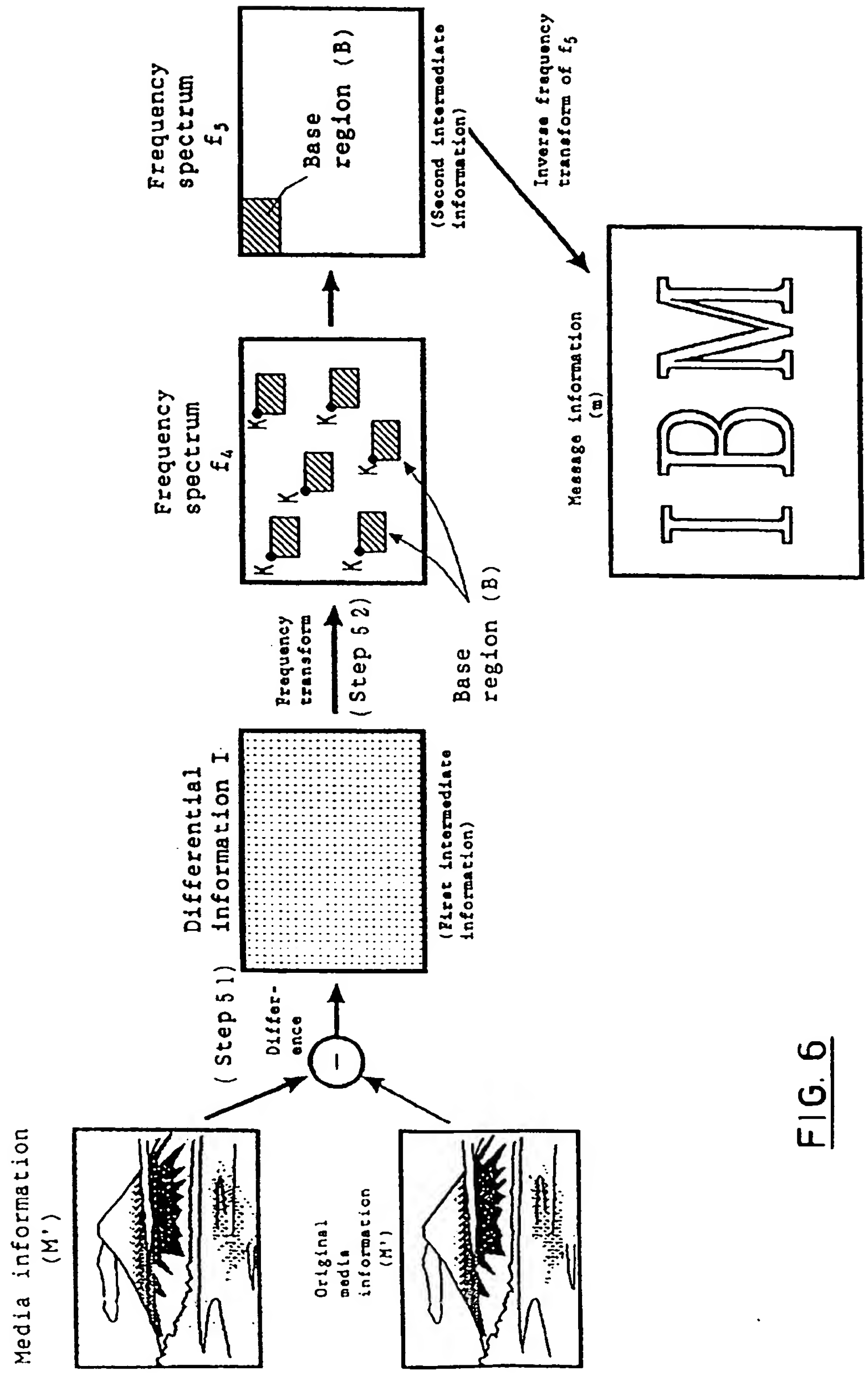

Media information (M')
Original media information (M')
(Step 5 1)
Differ-ence
Differential information I
(First intermediate information)
Frequency transform
(Step 5 2)
Frequency spectrum f_4
K
Base region (B)
Frequency spectrum f_5
Base region
region (B)
(Second intermediate information)
Inverse frequency transform of f_5
Message information (m)
IBM

FIG. 6

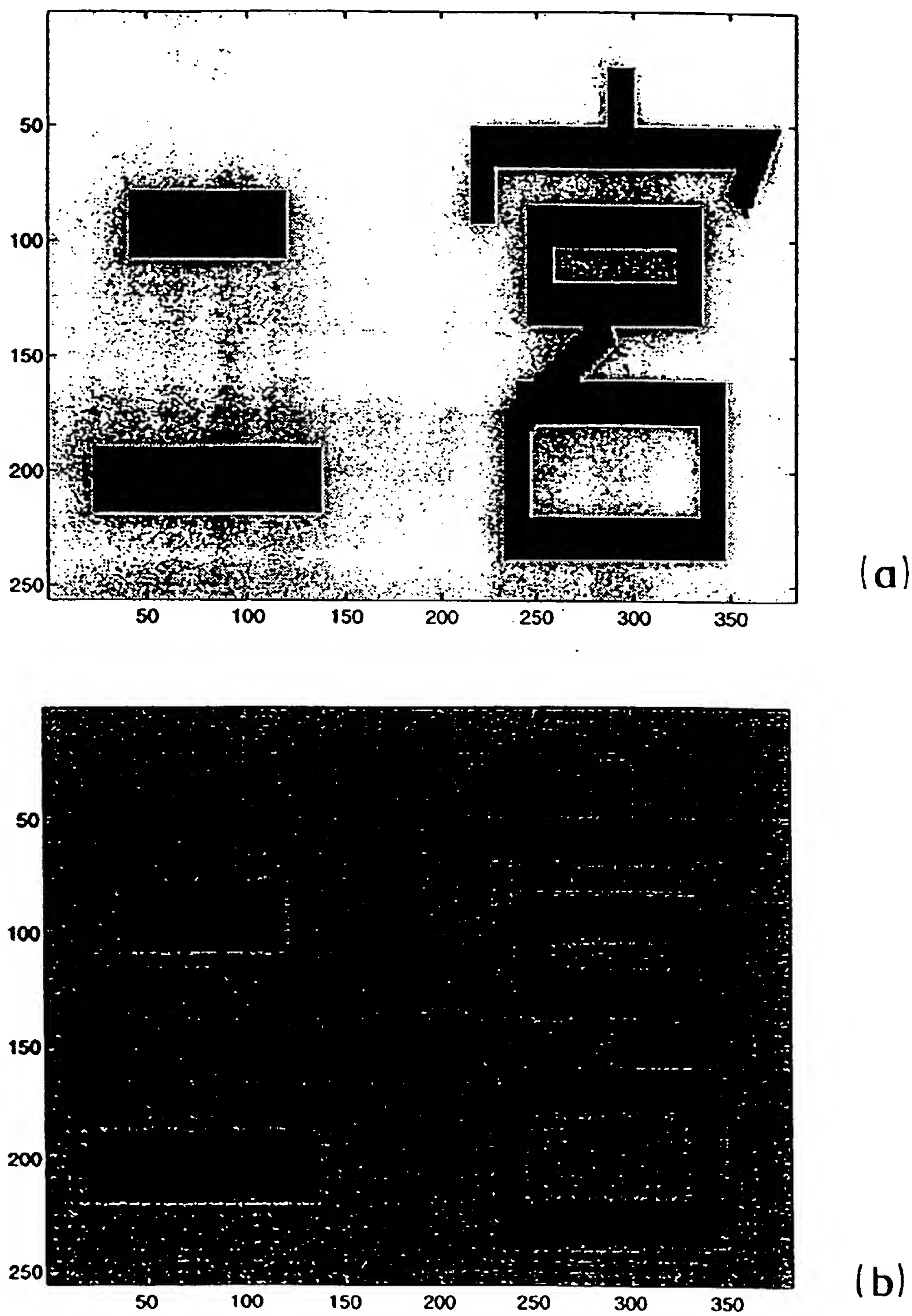
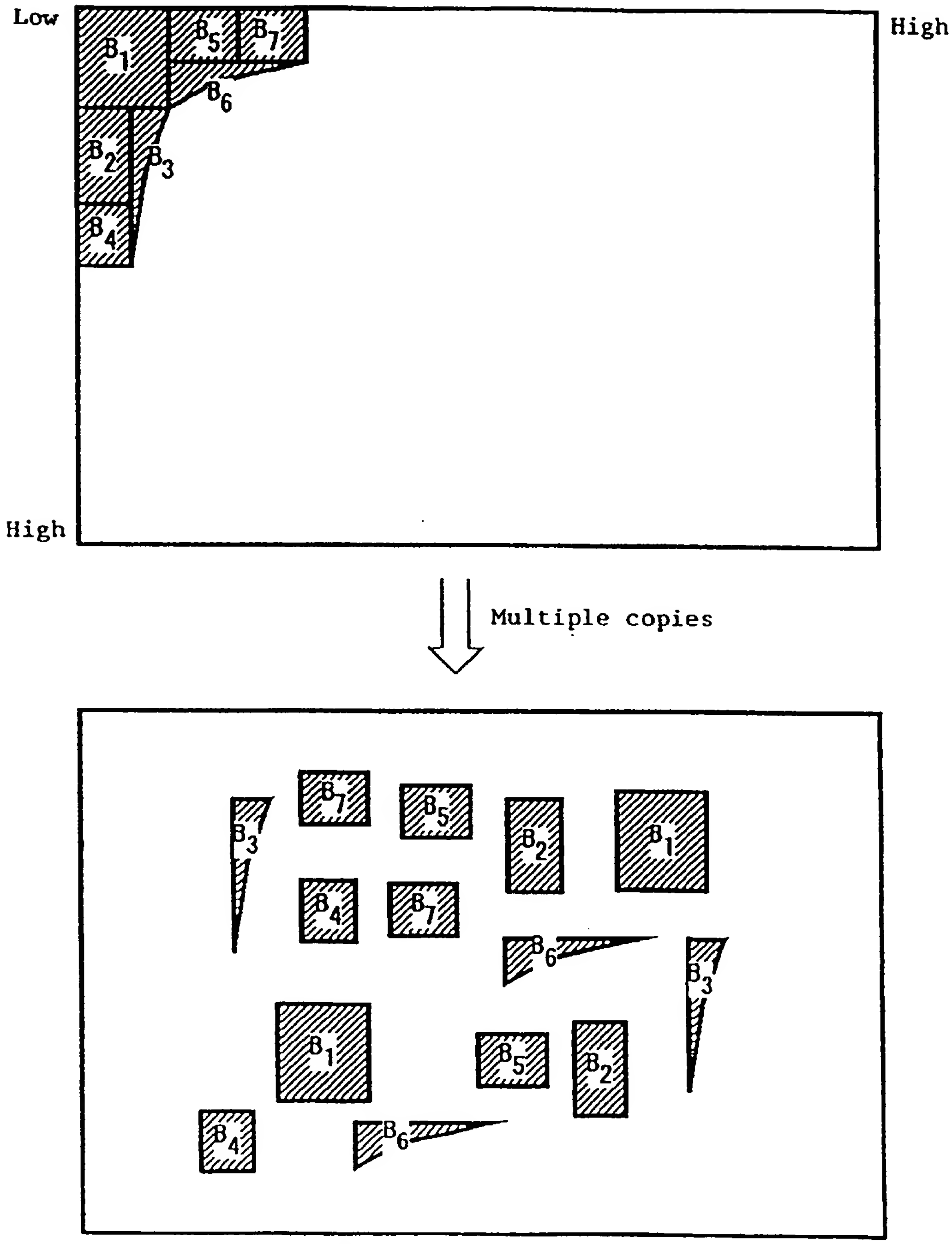

50
100
150
200
250
50
100
150
200
250
300
350
(a)
50
100
150
200
250
50
100
150
200
250
300
350
(b)

FIG. 7



Frequency spectrum f_3 (Intermediate information)

Multiple
degree 2

FIG. 8

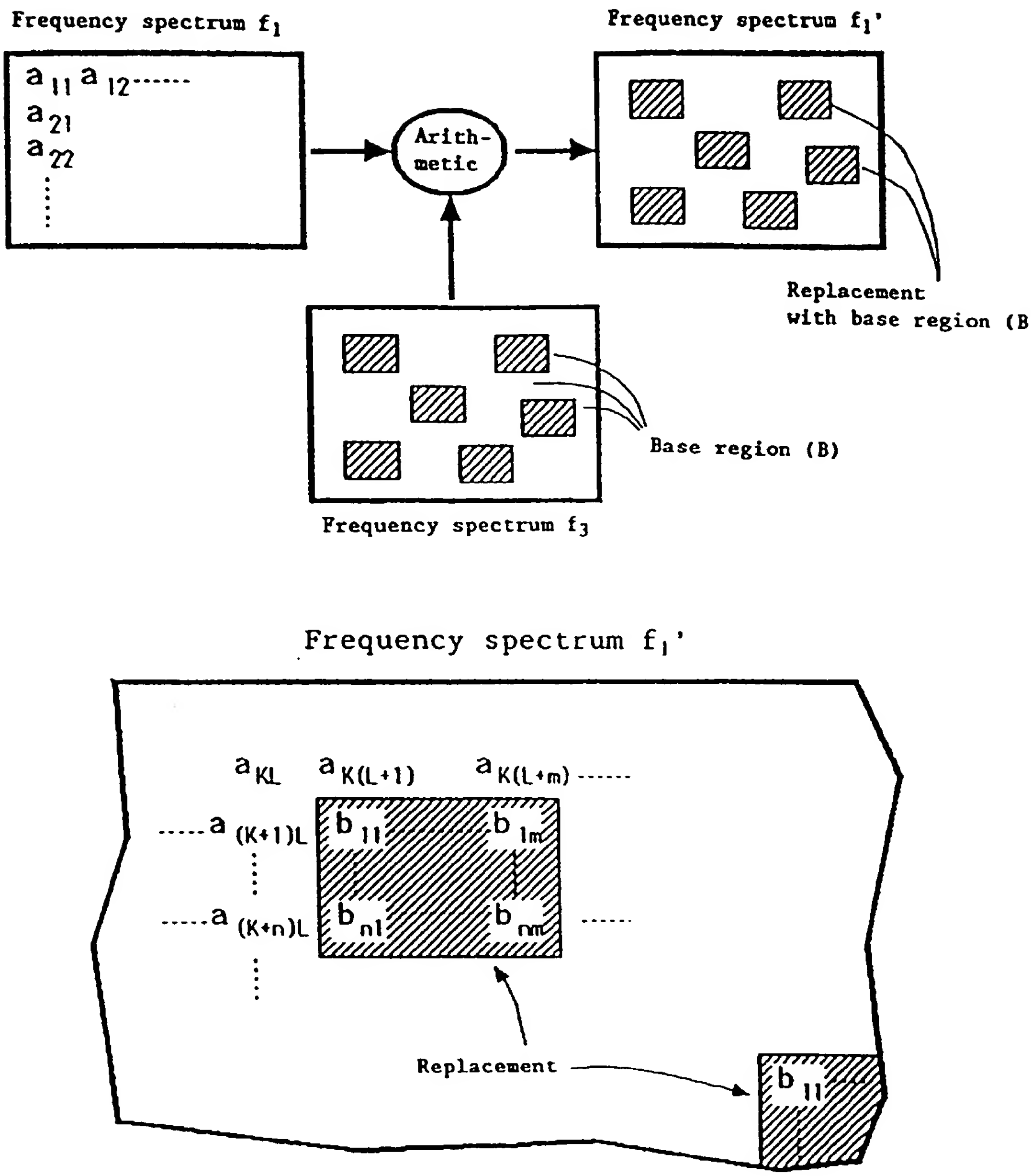

Frequency spectrum f_1
a_{11} a_{12}......
a_{21}
a_{22}
Arith-
metic
Frequency spectrum f_1'
Replacement
with base region (B)
Base region (B)
Frequency spectrum f_3
Frequency spectrum f_1'
a_{KL} $a_{K(L+1)}$ $a_{K(L+m)}$ ......
......$a_{(K+1)L}$
......$a_{(K+n)L}$
b_{11}
b_{1m}
b_{n1}
b_{nm}
......
Replacement
b_{11}

FIG. 9

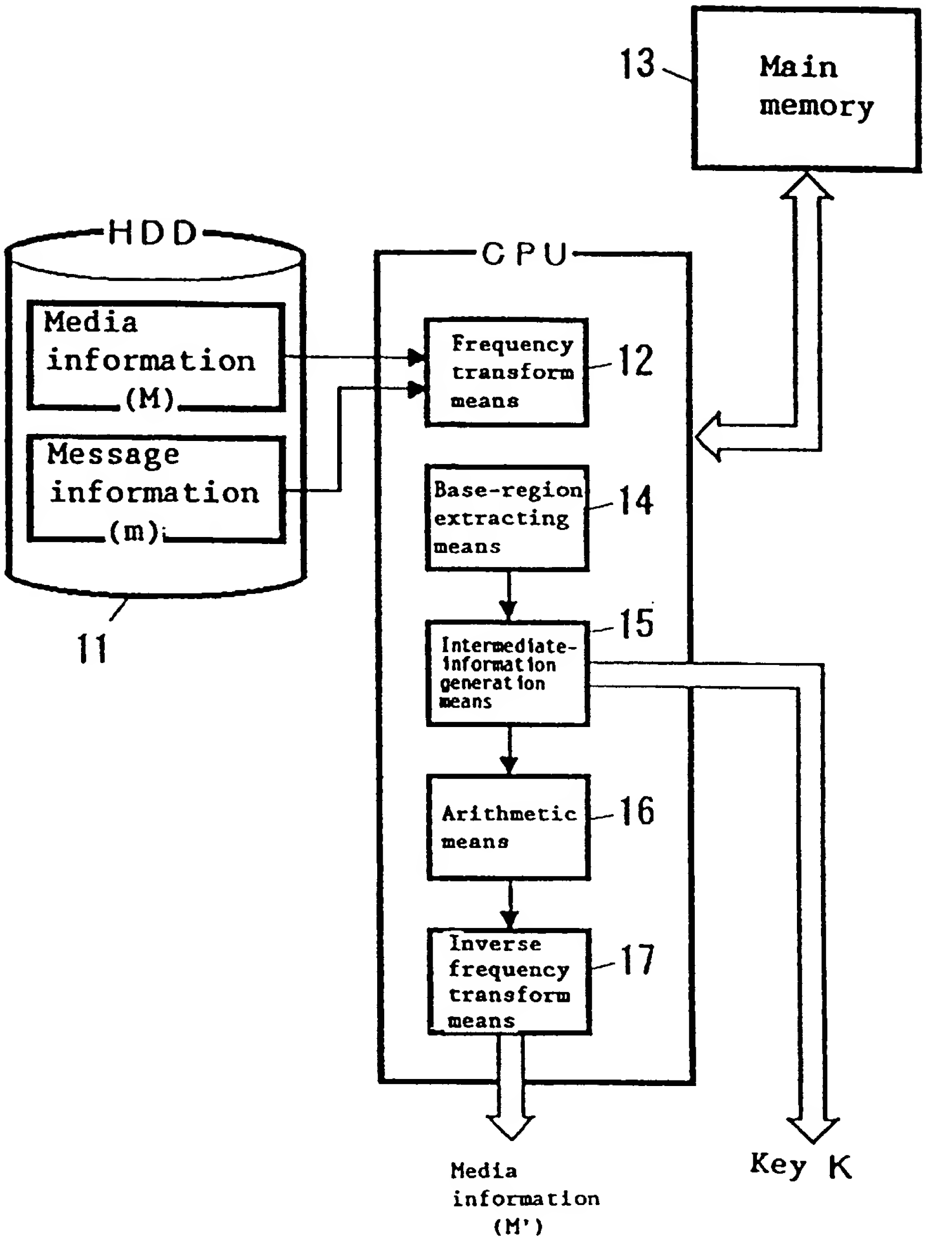

13
Main memory
HDD
Media information (M)
Message information (m)
11
CPU
Frequency transform means
12
Base-region extracting means
14
Intermediate-information generation means
15
Arithmetic means
16
Inverse frequency transform means
17
Media information (M')
Key K

FIG. 10

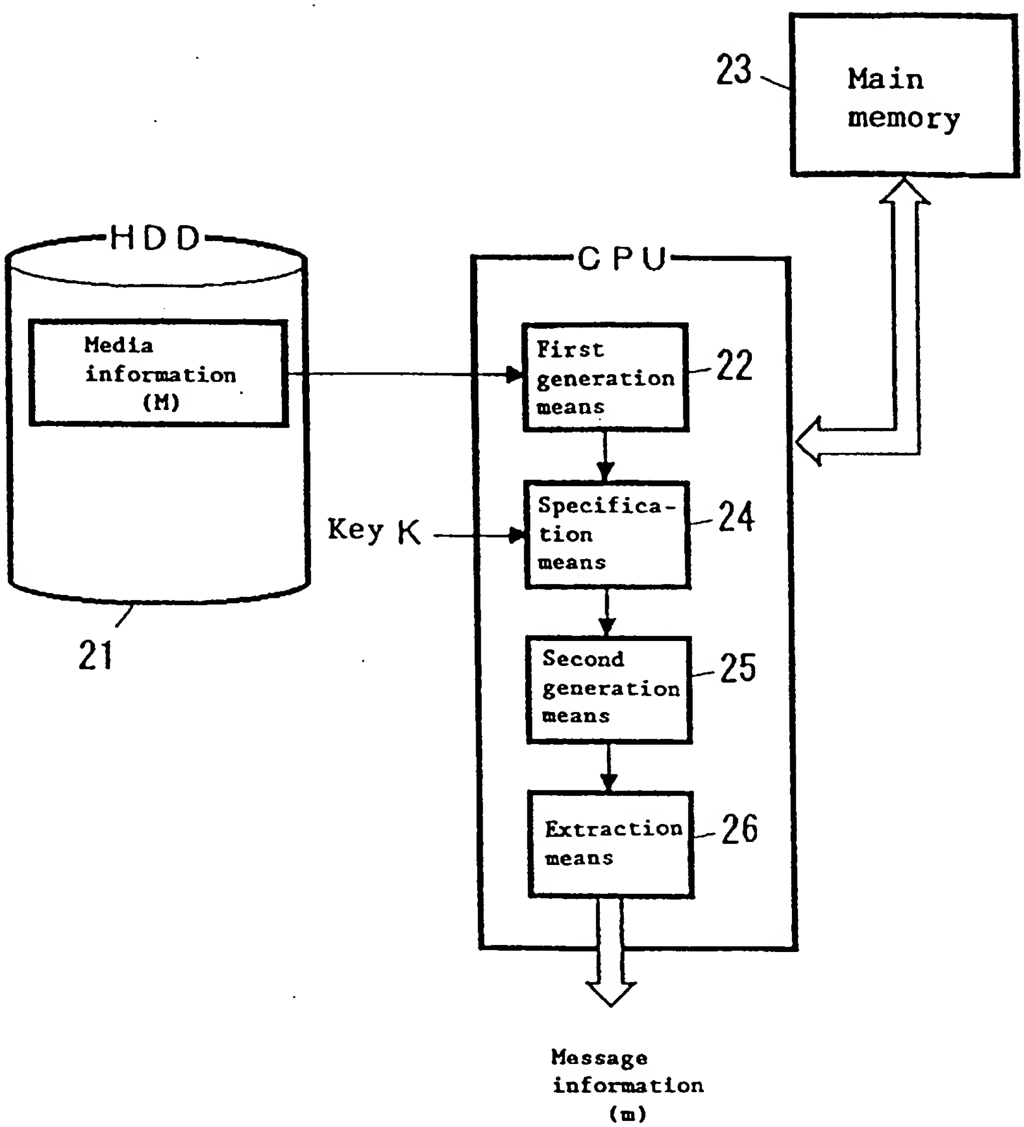

23
Main memory
HDD
Media information (M)
CPU
First generation means
22
Specification means
24
Key K
Second generation means
25
Extraction means
26
21
Message information (m)

FIG. 11